POTENTIAL FOR SPECT CAMERAS UTILIZING PHOTODIODE READOUT OF SCINTILLATOR CRYSTALS*. W.W. Moses, S.E. Derenzo, G.J. Gruber, R.H. Huesman, and T.F. Budinger, Life Science Division, Lawrence Berkeley Laboratory, Berkeley, CA.

We present a conceptual design for a SPECT detector consisting of an array of 3x3x5 mm CsI(Tl) scintillator crystals individually read out by an array of 3 mm square silicon photodiodes. The interaction position is not determined by Anger logic, but by the location of the individual crystal / photodiode element in which the gamma ray is observed. Since the design is modular (each module typically having 64 crystals, photodiodes, and charge amplifiers, and one multiplexer circuit to reduce the number of readout channels), a large variety of camera geometries can be realized. Advantages of this design over conventional cameras (NaI(Tl) scintillator / photomultiplier tube) are lower gain drift (*i.e.* higher stability), smaller size, significantly higher count rate capability, and potentially lower cost.

For the 141 keV emissions of Tc-99m, both CsI(Tl) and NaI(Tl) have 85-90% photoelectric fraction, but CsI(Tl) has an attenuation length of 3.0 mm as compared to 4.5 mm for NaI(Tl). Thus, a 5 mm thick CsI(Tl) camera has similar efficiency to a NaI(Tl) camera with a 7.5 mm thickness (between 1/4 and 3/8 inch). The light output of CsI(Tl) is 25% higher than that of NaI(Tl), and while its 565 nm emissions are not efficiently detected with photomultiplier tubes, they are well matched to photodiode detection.

This design concept was tested with a 3x4 element photodiode array with typical room temperature pixel parameters of 4 pF capacitance, 50 pA dark current, and 90% quantum efficiency. The signals from the scintillator crystals are amplified with a 16 channel custom integrated circuit that is less than 3 mm on a side. When a cylindrical (3 mm diameter, 5 mm high) CsI(Tl) crystal is coupled to an element of the photodiode array and excited with the 141 keV emissions of Tc-99m, a 12.1% fwhm energy resolution is observed at room temperature. Thus, a 40 cm square camera will have similar efficiency and only slightly poorer energy resolution than a conventional camera, but be more compact and have a maximum event rate of $5x10^6$ cps, greatly reducing transmission measurement time.

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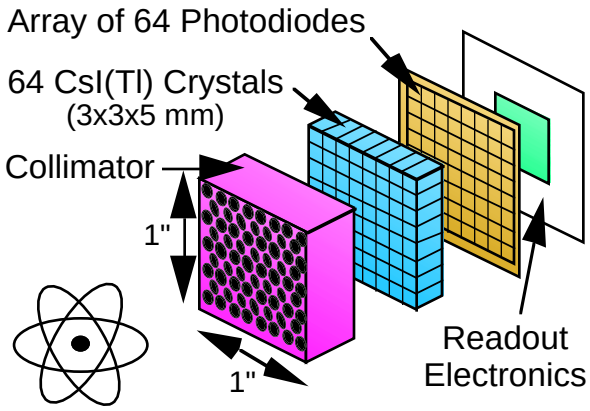
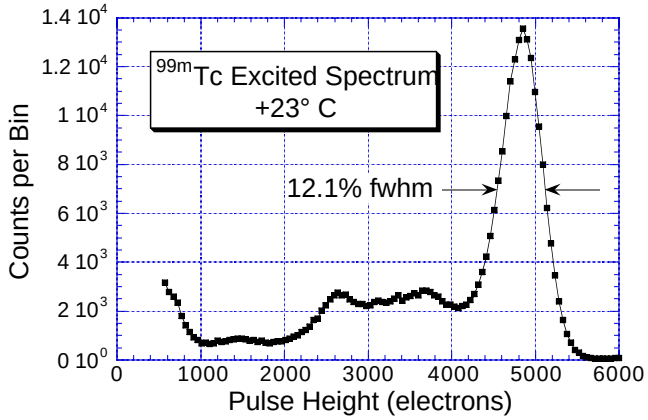
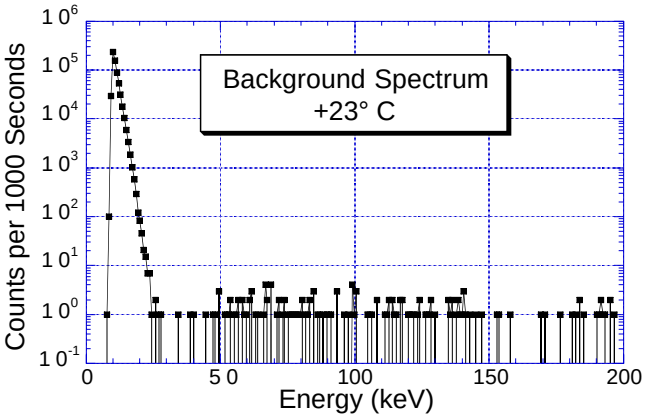


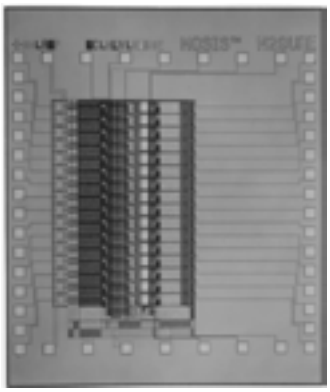
Detector Module Schematic.
Exploded view of the SPECT module. A conventional collimator provides collimation for the incident gammas, which are detected in individual 3x3x5 mm CsI(Tl) crystals. Each crystal is attached to a photodiode array element, which measures the energy of the incident photon and whose location identifies the crystal of interaction. The photodiode amplifiers and readout electronics are on a custom IC placed behind the photodiode array.

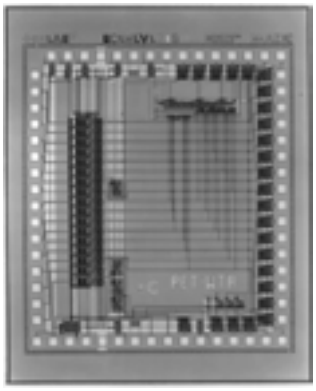


Energy Resolution.
A single 3 mm diameter, 5 mm high cylinder of CsI(Tl) is coupled to a 3 mm square pixel of a 3x4 element photodiode array. The signals are amplified with an IC amplifier and the detector operated at room temperature. The energy spectrum when excited by 141 keV gamma rays from ^{99m}Tc (shown at left) has 12.1% fwhm energy resolution. The energy resolution for the 511 keV and 1275 keV emissions of ^{22}Na is 8.5% fwhm and 6.1% fwhm respectively.



Background.
Since these devices must be self-triggered, the background "event" rate due to electronic noise must be low. This plot shows the pulse height spectrum at 23° C when the source is removed and data accumulated for 1000 seconds. Only 0.17 events/sec/pixel are observed with energy above 25 keV (probably due to cosmic ray interactions), and only 0.024 event/sec/pixel are observed in the 141±14 keV energy window.





Electronics.
Shown at the left is a picture of the 16 channel charge sensitive preamplifier and amplifier IC used for the measurements. At the right is a 16 channel "Winner-Take-All" IC, which is an intelligent multiplexer that can be used to determine the address of the channel with the highest signal and pass that analog signal to a discriminator for energy qualification. Both ICs are less than 3 mm on a side.